

Seasonal variation in intake of carotenoids and vegetables and fruits among white men in New Jersey^{1,2}

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ABSTRACT In a population-based case-control study of lung cancer among New Jersey men, usual adult consumption of many vegetables and fruits was included in the interview to assess the protective potential of carotenoids. With data from 900 controls the percentage of New Jersey white men who eat specific vegetables and fruits primarily in certain seasons, the relative importance of in-season and out-of-season consumption, and the median length of season were determined. Although first asking whether a food item was consumed all-year-round or primarily in certain seasons and then asking for the appropriate frequency of consumption facilitated the interview, obtaining out-of-season frequency of consumption and length of season was not necessary. Substituting 0 for reported out-of-season frequencies and 3 mo for reported season lengths reduced slightly the observed associations between diet and lung cancer risk but did not modify the overall pattern noted. Carotenoid intake in winter-fall was estimated to be about two-thirds that in summer-spring. *Am J Clin Nutr* 1987;45:107-14.

KEY WORDS Cancer, carotenoids, fruit, lung, seasonal, vegetables

Introduction

Beta-carotene has been proposed to reduce risk of cancer (1) possibly by capturing free radicals and protecting DNA and cell membranes from oxidative degradation (2, 3). In order to evaluate the protective potential of β -carotene in a case-control study, subjects are asked about their usual consumption of vegetables and fruits that are major sources of carotenoids. Inevitably the question arises of how to assess usual adult consumption of vegetables and fruits that may be eaten at different frequencies during different times of the year. With many exposures to include in the interview, time cannot be allotted to determine in-season and out-of-season frequencies of consumption of food items unless truly necessary.

During 1980-82, the Environmental Epidemiology Branch of the National Cancer Institute and the New Jersey State Department of Health carried out a large case-control study of lung cancer among New Jersey men (4). A major objective was to evaluate the role of carotenoids, preformed retinol, and total vitamin A in lung carcinogenesis. For most vegetables and fruits included in the dietary section of

the interview, subjects were asked if the food was eaten primarily during certain seasons and if so, the details. With data collected from control subjects in this study, we have been able to evaluate what percentage of New Jersey white men eat certain vegetables and fruits primarily in certain seasons, the relative importance of in-season and out-of-season consumption, and the median length of the season. We have also assessed the need to collect actual details of seasonal consumption patterns by making various assumptions about the nature of seasonal intake and then by recalculating the salient relative risks (RRs) from our analysis of the relationship of diet to lung cancer. In addition, we have compared estimates of summer and winter carotenoid intake

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among New Jersey white men and evaluated their relationship to risk of lung cancer.

Throughout this paper seasonality refers not to agricultural or commercial availability but to actual dietary patterns. For example, canned peaches may be stocked on grocery store shelves all-year-round, but if they are eaten primarily in winter, their consumption is viewed as seasonal. Analogously, even though fresh tomatoes are cheaper, tastier, and more abundant in summer if they are eaten all-year-round and not primarily in summer their consumption is not considered to be seasonal.

Methods

During 1980–82 a population-based incident case-control study of lung cancer among white men was carried out in six high-risk areas of New Jersey (4). Control subjects, who are the focus of this analysis, were randomly selected from New Jersey licensed drivers for subjects directly interviewed and from the New Jersey mortality files for subjects for whom surrogates had to be interviewed, either because the subject had died or was incapacitated. Of 1415 white control subjects identified for the study, interviews were successfully completed for 900 (64%). Reasons for nonparticipation included respondent refusal (25% of those selected), respondent not traceable (9%), and poor interview (3%).

Diet was assessed by asking about the usual frequency of consumption, ~4 yr earlier, of 44 food items. Included were the major sources of preformed retinol (dairy products, eggs, liver, and fortified cereal) and carotenoids (vegetables, fruits, and juices). For most vegetables and fruits, respondents were asked whether they ate the food during the entire year, primarily in certain seasons, or not at all. For foods that the respondent said were eaten primarily in certain seasons, frequency of consumption both in-season and out-of-season and the length of season were obtained. Frequency of consumption was obtained in times per day, week, month, or year with the respondent choosing for each food item whichever mode was most convenient.

Actual seasons in which the vegetables and fruits were primarily consumed were not obtained in the interview but were determined with household-food consumption data by season for the Northeast US collected by the US Department of Agriculture (USDA) during 1977–78 (5).

For food groups such as dark green vegetables, dark yellow-orange vegetables, and fruits, frequency of consumption was calculated as the simple sum of the frequencies of consumption of the food items comprising the food group. Nutrient indices were calculated as the weighted sum of the frequencies of consumption of the food items containing the nutrients with the weights being the nutrient contents of typical portions of food items (6, 7). Age-specific portion sizes for white adult men were approximated on the basis of two recent national nutrition surveys (8, 9). Carotenoid index included the 25 potentially seasonal vegetables and fruits listed in Table 1 along with

TABLE 1
Seasonalness of consumption of common vegetables and fruits

Food item	Percent consuming food		
	All year	Primarily in one season	Not at all
1) Fresh tomatoes	27	66	7
2) Head lettuce	73	12	15
3) Leaf lettuce	25	12	63
4) Green cabbage	73	6	21
5) Carrots	66	2	32
6) Mixed carrots*	85	1	13
7) Green pepper	58	18	24
8) Red pepper	21	5	74
9) Green beans	89	6	6
10) Green peas	89	2	9
11) Asparagus	36	30	34
12) Broccoli	68	7	25
13) Greens	69	4	27
14) Corn	49	42	8
15) Summer squash	22	28	50
16) Winter squash	11	8	81
17) Yams, pumpkin	66	15	19
18) Avocado	6	3	90
19) Canteloupe	9	70	22
20) Watermelon	5	66	29
21) Fresh peaches	4	77	20
22) Canned peaches	61	5	34
23) Nectarines	4	36	59
24) Apricots	20	8	72
25) Pink grapefruit	31	21	48

* Carrots served mixed with other vegetables or in salad or stew.

several other foods which were assumed to be consumed on a relatively constant basis throughout the year: 26) prunes-prune juice, 27) tomato juice-vegetable juice, 28) grapefruit juice, 29) cooked tomatoes-tomato sauce, 30) cornbread-corn grits-tortillas, and 31) hot red chili peppers. Indices for several other nutrients correlated with vegetable and fruit intake, such as vitamin C, could not be formed because the questionnaire did not include enough of the foods rich in these nutrients.

Occasionally respondents would not know if a food item was eaten, or if eaten how often it was eaten, or details of seasonality of consumption. The 12 control subjects (1.3%) for whom five or more food items had these types of nonquantitative responses were eliminated from the analysis. The remaining 888 control subjects had quantitative responses to 99.8% of the questions pertaining to food items. Appropriate medians were substituted for nonquantitative responses in calculating intake of food groups and nutrients but not intake of food items. For example, the median level of consumption among those who ate a food for the entire year was used when it was known that the food was eaten over the entire year but not how often; the median level of consumption in season among seasonal consumers was used when it was known that the food was eaten seasonally but not how often.

Of the 888 control subjects, 562 (63%) were interviewed directly. The 326 surrogate interviews were with wives (69%), children (21%), siblings (9%), or other relatives (2%).

Results

The ages of the 888 study subjects ranged from 26 to 90 yr with a median age of 65. Included were 871 (98%) whites and 17 (2%) Hispanics.

For 25 vegetables and fruits, the percentage of subjects who ate the food item all-year-round, primarily in certain seasons, or not at all is shown in Table 1. Unless otherwise specified, all forms of the food—fresh, frozen, or canned; raw or cooked—were included since processing and preparation methods do not significantly affect carotenoid content. Use in a salad was also included.

In general, fruits such as canteloupe, watermelon, fresh peaches, nectarines, and fresh tomatoes were eaten by many more people primarily in one season rather than all-year-round; only apricots (including canned and dried forms), canned peaches, and pink grapefruit were eaten by more people all-year-round than primarily in one season. In contrast to fruits, all vegetables except summer squash were consumed by more people all-year-round than primarily in one season. For most vegetables (head lettuce, green cabbage, carrots, green pepper, red pepper, green beans, green peas, broccoli, greens, and yam-pumpkin) many more subjects, 3–45 times as many, ate the food all-year-round rather than seasonally.

Relatively high percentages of the white men in New Jersey reported never eating certain common vegetables. For example, 81% never ate winter squash; 50%, summer squash; 32%, raw or cooked carrots served alone; 27%, green leafy vegetables of any kind; and 25%, broccoli.

Median frequencies of consumption over a year period for all-year consumers and seasonal consumers are shown for the 25 vegetables and fruits in Table 2. For seasonal consumers frequency of consumption over a year was a time-weighted average of higher in-season consumption and the lower out-of-season consumption. For nearly all the vegetables, all-year consumers ate the food more often over a year interval than did seasonal consumers; only green beans were eaten more times during a year by the seasonal consumers than by the all-year consumers. For fruits not readily available out of season, such as canteloupe, watermelon, and nectarines, seasonal consumers ate the food more often

over a year interval than did all-year consumers, but for fruits that are available out of season, such as fresh tomatoes and fresh peaches, all-year consumers ate the food more times during a year.

For those who ate a vegetable or fruit primarily in certain seasons, median frequencies of consumption in season and out of season and median season length are also shown in Table 2. Among seasonal consumers median out-of-season consumption levels were 0 times per month for all vegetables and fruits other than green beans, green peas, corn, head lettuce, and fresh tomatoes, and for head lettuce and fresh tomatoes out-of-season intake was more than an order of magnitude less than in-season intake. Median length of season was usually 3 mo with longer seasons reported for carrots, avocado, canned peaches, and pink grapefruit and shorter seasons for asparagus, yams-pumpkin, fresh peaches, nectarines, and apricots.

Results presented in Tables 1 and 2 were also calculated separately for those interviews conducted with the study subject and those conducted with a surrogate respondent. There were no major differences.

Smoking-adjusted relative risks of lung cancer for nutrient and food group intake among current and recent cigarette smokers [Table 3 of reference (4)] were fundamental in the analysis and interpretation of our case-control study of lung cancer in New Jersey white men. For vegetables and fruit, vegetables, dark green vegetables, dark yellow-orange vegetables, fruit, and carotenoids, risk increased with decreasing intake with RRs for those in the lowest quartile of consumption, compared with those in the highest quartile, ranging from 1.7 to 2.2 (4). For these calculations all details on seasonal consumption obtained from each study subject were used. In order to assess the need for obtaining such specific information, two simplifying assumptions about seasonal consumption were made and RRs were recalculated: 1) because median reported out-of-season frequency of consumption was 0 for so many food items, 0 was substituted for out-of-season frequencies of consumption for all food items consumed seasonally by cases or controls; and 2) because median reported length of season was usually 3 mo, this value was substituted for length of

TABLE 2
Median frequency of consumption of common vegetables and fruits for all-year and seasonal consumers

Food item	Median frequency of consumption averaged over a year (servings/mo)		Seasonal consumers		
	All-year consumers	Seasonal consumers	Median frequency of consumption (servings/mo)		Median length of season <i>mo</i>
			In season	Out of season	
Fresh tomatoes	12.9	7.5	30	0.4	3
Head lettuce	12.9	6.9	17	1	3
Leaf lettuce	4.3	2.9	9	0	3
Green cabbage	2.0	1.4*	4*	0*	3*
Carrots	4.3	2.1†	4†	0†	4†
Mixed carrots	4.3	2.1†	4†	0†	6†
Green pepper	4.3	2.7	9	0	3
Red pepper	2.0	2.1*	9*	0*	3*
Green beans	4.3	5.7	9	4	3
Green peas	4.3	3.6†	9†	3†	3†
Asparagus	2.0	1.1	4	0	2
Broccoli	2.5	1.5	4	0	3
Greens	2.5	1.1*	4*	0*	3*
Corn	4.3	3.6	9	2	3
Summer squash	2.0	1.4	4	0	3
Winter squash	1.0	0.7	4	0	3
Yams, pumpkin	1.0	0.4	2	0	2
Avocado	0.5	2.0*	9*	0*	4*
Cantaloupe	1.0	1.4	4	0	3
Watermelon	0.2*	0.7	4	0	3
Fresh peaches	4.3*	2.1	11	0	2
Canned peaches	2.0	3.0*	4*	0*	6*
Nectarines	0.4*	1.4	9	0	2
Apricots	1.0	1.1	4	0	2
Pink grapefruit	2.0	2.1	9	0	4

* Includes ≤ 50 subjects.

† Includes ≤ 25 subjects.

season for all food items consumed seasonally by cases or controls. In **Table 3** are shown recalculated RRs and the change from the RRs based on the more detailed information on seasonality obtained in the interview. Practically all RRs that were noticeably elevated for low and moderate consumers were reduced by 0.1. Although such changes weakened the individual associations, they did not modify the overall pattern noted.

In order to compare consumption of carotenoids and related food groups during summer and winter, the in season for each vegetable and fruit was categorized as summer-spring or winter-fall on the basis of the USDA 1977-78 Food Consumption Survey (5). Green cabbage, carrots, green peas, broccoli, winter squash, yams-pumpkin, canned peaches, and pink grapefruit were eaten more frequently in

winter-fall than in summer-spring; all the other vegetables and fruits listed in **Table 1** were consumed more frequently in summer-spring. Frequency distributions for consumption of carotenoids and related food groups during summer-spring, winter-fall, and over an entire year were calculated. The levels of consumption of individuals with relatively low intake (those at the 50th, 25th, and 10th percentiles of each distribution) are presented in **Table 4**. Frequency distributions for intake of vegetables, dark green vegetables, and dark yellow-orange vegetables did not vary much between summer-spring and winter-fall. However, for carotenoids and total vegetables and fruits median consumption in winter-fall was about two-thirds the median consumption in summer-spring, and the 10th percentile of consumption in winter-fall was an even smaller proportion

TABLE 3

Smoking-adjusted relative risks of lung cancer for nutrient and food group intake among current and recent cigarette smokers*

Nutrient or food group	Level of consumption			p for trend
	Upper 25%	Middle 50%	Lower 25%	
Retinol	1.0	1.0 (-0.1)†	1.0	0.50
Carotenoids	1.0	1.5	1.6 (-0.1)	0.02
Vitamin A (International Units)	1.0	1.0	1.5	0.02
Vitamin A (Retinol Equivalents)	1.0	1.2	1.1 (-0.1)	0.34
Dairy products	1.0	0.8	0.9	0.28
Vegetables and fruit	1.0	1.6 (-0.1)	1.7 (-0.1)	0.01
Fruit	1.0	1.4	1.1 (-0.1)	0.40
Vegetables	1.0	1.2 (-0.1)	1.6 (-0.1)	0.01
Dark green vegetables	1.0	1.3 (-0.1)	1.7 (-0.1)	0.005
Dark yellow-orange vegetables	1.0	1.5 (-0.1)	2.1 (-0.1)	< 0.001

* Current cigarette smokers are current smokers and those who quit within 1 yr of diagnosis. Recent smokers are those who quit 2-5 yr prior to diagnosis. Smoking was controlled by adjusting over 4 strata: low intensity (< 25 cigarettes/day) and low duration (\leq 40 yr); low intensity and high duration (> 40 yr); high intensity (\geq 25 cigarettes/day) and low duration; and high intensity and high duration. Low, moderate, and high levels of consumption of each food group and nutrient were the same as in (4). Included for analysis are 524 case and 354 control subjects.

† In parentheses is the change in RR that resulted from the two simplifying assumptions about seasonal consumption.

of that in summer-spring (62%, 56%, respectively). Fruit intake was much less frequent in winter-fall than in summer-spring with the median level of consumption in winter-fall about one-third that in summer-spring.

Smoking-adjusted relative risks of lung cancer among current and recent cigarette smokers were calculated for summer-spring and winter-fall consumption of carotenoids, vegetables and fruit, fruit, vegetables, dark green vegetables, and dark yellow-orange veg-

etables in the same manner as they had been calculated for consumption over the entire year [Table 3 of reference (4)]. In each case low, moderate, and high intake of each food group and the carotenoid index were defined by splitting the frequency distribution among the controls in the study population at the 25th and 75th percentiles. No steeper increase in risk with decreasing intake was seen for the estimates of intake in winter-fall than for the annual estimates.

TABLE 4

Frequency of consumption of carotenoids and related food groups in summer-spring, winter-fall, and averaged over a year

Nutrient index or food group	Frequency of consumption								
	Summer-spring			Winter-fall			Over a year		
	50%ile	25%ile	10%ile	50%ile	25%ile	10%ile	50%ile	25%ile	10%ile
Carotenoids in REs/mo*	22 000	14 400	9 000	14 500	9 000	5 600	16 200	10 200	6 300
Vegetables and fruits in servings/mo (1-29)†	128	90	61	79	54	34	91	63	41
Fruits in servings/mo (1, 18-28)	59	36	19	19	9	3	31	16	9
Vegetables in servings/mo (2-17)	61	40	26	50	32	21	52	34	22
Dark green vegetables in servings/mo (3, 7, 9, 10, 12, 13, 15/2‡)	23	14	9	20	13	8	20	13	8
Dark yellow-orange vegetables in servings/mo (5, 6, 8, 16, 17)	9	4	2	9	4	2	9	4	2

* Retinol Equivalents.

† Numbers in parentheses identify food items comprising the food group and refer to numbers listed in Table 1 and Methods. Carotenoid index was formed as described in Methods.

‡ Frequency of consumption of summer squash was multiplied by $\frac{1}{2}$ on the assumption that half the summer squash eaten was green zucchini and half was yellow crookneck.

Discussion

In pretesting interviews for our case-control study of lung cancer in New Jersey, we discovered that when we asked how often seasonal foods were eaten and failed to specify whether the question referred to all-year-round or in season only subjects often floundered and asked for clarification. When we modified the interview so that subjects could first answer whether they ate the food equally often in all seasons or primarily in a single season and then focused the frequency question, the interview seemed to move more smoothly and quickly even though more questions were involved.

Although first determining if vegetables and fruits were consumed all-year-round, primarily in certain seasons, or not at all facilitated the interview, it was not necessary to obtain out-of-season frequency of consumption and length of season if the food was eaten seasonally. Among primarily seasonal consumers, median out-of-season frequency of consumption was either 0 or an order of magnitude less than in-season frequency for all but three vegetables; although the median length of season ranged from 2 to 6 mo, it was usually 3 mo. Substitution of 0 for the out-of-season frequencies of consumption for all food items and substitution of 3 mo for the length of season for all food items did reduce the strength of the principal dietary associations noted in our analysis of the etiology of lung cancer in New Jersey men. In general, misclassification of exposure will bias results toward the null hypothesis (10). However, the overall pattern of risk remained discernable and essentially unchanged.

For fruits generally eaten fresh—cantaloupe, watermelon, peaches (excluding canned peaches), nectarines, and tomatoes (excluding cooked tomatoes)—most of the subjects who ate them did so primarily in season. However for vegetables except summer squash, the majority of subjects who ate them did so all-year-round probably because vegetables are either available fresh all-year-round (lettuce, cabbage, carrots, peppers, greens) or are available in frozen and canned forms (carrots, green beans, peas, broccoli, greens, corn, winter squash, yams-pumpkin).

Availability of a food throughout the year influenced not only the percent of subjects who

ate the food primarily in certain seasons but also whether seasonal or all-year-round consumers ate more of the food item over a year interval. For fresh fruits primarily available in one season (cantaloupe, watermelon, nectarines, pink grapefruit, avocado), seasonal consumers ate more portions over a year than did all-year-round consumers. Apparently those who perceived themselves as all-year-round consumers of these fresh fruits ate them relatively infrequently and did not take advantage of greater availability when the fruit was in season. However, for fresh tomatoes, which are available throughout the year in New Jersey, all-year-round consumers ate more portions over a year than did seasonal consumers. Similarly, for nearly all the vegetables all-year consumers ate more portions over a year interval than seasonal consumers probably because the vegetables are available all-year-round in fresh, frozen, or canned varieties.

There are few databases that include seasonal consumption of specific vegetables and fruits with which to compare our observations. HANES I and II, the first and second Health and Nutrition Examination Surveys of the United States, administered 24-h dietary recalls to residents of Southern states primarily in winter and to residents of Northern states primarily in summer (8, 11) thus confounding seasonal dietary patterns with regional patterns. The 1977–78 USDA Food Consumption Survey collected 24-h recalls and 2-day food diaries during summer, winter, spring, and fall, but seasonal consumption data for specific food items have not been published for individuals or for individuals grouped according to region of the country (5, 12). The HANES I Epidemiologic Follow-up Survey (13, 14) did ask ~11 000 adults whether they consumed a number of individual vegetables and fruits primarily during certain seasons of the year, if so how often the vegetables and fruits were eaten during this period, and if not how often the vegetables and fruits were eaten all-year-round, but the data are not yet analyzed.

Serum carotenoid levels are correlated with recent carotenoid consumption (15, 16) and are not maintained within a narrow physiologic range like serum vitamin A levels. The half-life of carotenoids in the serum is not known but is believed to be of the order of

days or weeks. Our data on white men in New Jersey indicate that total carotenoid intake may be 50–60% higher in the summer than in the winter. If carotenoids in general do play a protective role in the etiology of cancer (4, 17), then winter may be a time of special vulnerability. However, when the study population was ranked according to winter-fall intake of carotenoids rather than annual intake, there was no increase in the lung cancer risk associated with relatively low intake. One reason may be that dark yellow-orange and dark green vegetables were more strongly associated with reduced risk of lung cancer than with the carotenoid index, and consumption of these two classes of vegetables did not vary noticeably during the year.

Distinct differences between summer and winter were also noted for vegetable and fruit intake and were largely attributable to seasonal differences in fruit consumption. However, common winter fruits, such as apples, pears, and bananas, were not included in the interview since they do not contain high levels of carotenoids, and the food group fruits was therefore substantially incomplete.

The median intake of carotenoids [22 000 Retinol Equivalents (REs)/month or 73% of the Recommended Dietary Allowance for vitamin A/day (18)] and the median intake of vegetables and fruit (128 servings/month or 4.3 servings/day) seem high for adult men especially since vegetables and fruits low in carotenoids were not included in the interview. However, even if a vegetable or fruit was included in a tossed salad, fruit salad, vegetable mixture, stew, or other combination dish, it still was counted as a serving, which could explain part of the apparent overestimate.

One remarkable result of this analysis was the relatively high percentage of white men in New Jersey who never ate certain common vegetables and fruits. For example, 32% never ate raw or cooked carrots served alone; 27%, green leafy vegetables of any kind; and 25%, broccoli. If dark green and dark yellow-orange vegetables do reduce the risk of cancer, as suggested by our case-control study of lung cancer (4) and corroborated by several other studies (19–21), then these men may possibly be jeopardizing their health by avoiding these foods.

Carotenoids are not the only constituent of vegetables and fruits that have been proposed

to prevent cancer and that are being evaluated in case-control studies. Dietary fiber is believed to reduce the risk of colorectal cancer (22), and cruciferous vegetables have also been associated with reduced risk of colorectal cancer possibly because of certain indoles that they contain (23). Vitamin C has been postulated to protect against cancer (17, 24) as have certain plant phenols (3). Assessment of the dietary intake of all these compounds will require estimation of usual vegetable and fruit consumption over a period of years and a systematic way to handle seasonal variation. ☛

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